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ALTA AVALANCHE STUDY CENTER

Miscellaneous Report No. 5

EFFECTS OF METHODS OF SLOPE PACKING AS DETERMINED BY THE RAM PENETROMETER

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A conference on Slope Maintenance Problems was held at Winter Park, Colorado, on February 6 & 7, 1962. Most of the members who participated in this meeting were directly connected with ski area management. However, I was asked to participate by means of making penetrometer graphs on prepared plots in an attempt to find which method of slope packing would produce snow that was less likely to be displaced by continual skier action, the largest factor in the production of moguls.

On the 4th of February, Mr. Steve Bradley prepared 12 plots by various means of packing commonly used by ski areas in the high alpine zone (Colorado). During the afternoon of the 6th of February, penetrometer tests were taken, one test per plot, on each plot.

The penetrometer -- ram sonde -- is an instrument developed by the Swiss to investigate the nature of the snowpack. It is a sectional rod, graduated in centimeters, which is driven into the snowpack by blows of a falling weight. The objective is to determine the resistance to penetration of the various layers within the snowpack. The method of using this instrument is described in USDA Handbook No. 194 "Snow Avalanches" (FSH2 2332.81).

The plots were located in an undisturbed area and the different methods of packing took place about 48 hours before the penetrometer tests were made.

See series of bar graphs (ram profiles) on attached chart.

The profiles are all drawn using the same scale. The computations made by using the standard formula all are in the metric system.

Plot No. 1 - This is the control plot and for its whole depth it offered very little resistance to the penetrometer. This indicates a weak snow mass from top to bottom. This type of profile will usually support a skier, due to the planing properties of the ski, under high speed travel. However, if the skier slows down or stops, floatation is extremely poor and the skis break through the whole mass until the ground is reached.

Plot No. 2 - Shows how the resistance was increased by sidestepping on skis with one pass across the plot. The top few inches of snow increases in resistance due to disturbance and age hardening. The center of the snow pack also indicates increased resistance, but was probably not caused by the application of pressure by the skis. This increase was probably caused by another external force, a ski track perhaps, earlier in the winter.

Plot No. 3 - The plot was ski packed by four passes across it. Both plot 2 and 3 indicate approximately the same resistance in the top layer. It would appear that four trips across a snow mass gives no better results than one trip. Notice the small amount of resistance from the ground upwards to about the 50 cm. mark. The snow is very unstable and is composed of depth hoar.

Plot No. 4 - This plot was boot packed thoroughly as is usually done on highly competitive ski race courses such as in the Olympics. After the boot packing, the surface was smoothed out by ski packing.

As can be seen, this appears to be the most favorable method of producing the hardest ski surface which would resist the cutting action of the skis. This method produced the highest average resistance as offered to the penetrometer. This is also a method used on some slopes to prevent large climax avalanches from being set in motion during the winter.

A method of this sort takes much manpower and time and is usually not adaptable to normal ski area operations.

Plot No. 5 - In this plot sodium chloride (Na Cl), common table salt or rock salt, was added to the snow surface in an unknown amount. However, the application was considered as lightly salted. The salt was then boot packed into the snow, causing a fairly good mixture of salt and snow throughout the total depth. After the boot packing, the surface was smoothed out by ski packing. This caused a very pronounced high resistant snowpack from top to bottom. Also, it will be noticed that the total depth of the snow was reduced by almost half. This method has been used on isolated race courses but again is probably too expensive for general ski area use.

A slight deviation from this method might be worth trying on a ski area, i.e. lightly scatter the salt and then allow normal skiing pressure to take the place instead of the expensive proposition of boot packing and organized ski packing. The addition of salt by this method should be carefully controlled because of possible damage to vegetation during spring melt.

Plot No. 6 - This plot was basically the same as plot 5 except salt was broadcast liberally and after the boot packing the snow surface was not smoothed with the skis. The total depth of snow was reduced by about one-half but it appears that too much salt will cause adverse effects. The average resistance is only one-half that of the lightly salted area.

It would appear that a workable method for normal ski area operations might be found somewhere between the plot 5 method and the plot 6 method.

Plot No. 7 - This plot was prepared by simply broadcasting liberal amounts of salt and doing nothing else. By comparing plot 1, control, by plot 7, salted only, it is apparent that too much salt can be applied causing detrimental effects. Plot 7 has less average resistance than the control plot. So much salt was added that the snow was actually slushy.

The next series of plots, 8 through 12, were all prepared by some type of machine used in normal ski area operations. No. 8 was packed by a single pass of a Kristi oversnow vehicle, No. 8A with a single pass of a light snow roller. No. 9 was packed by two passes of the Kristi, and No. 9A by two passes of the light roller. An attempt was made to pack No. 10 with an Oliver tractor, but it stuck in the snow and had to be dug out (no ram profile was collected). Plots No. 11 and 12 were compacted with one and two passes, respectively, of a heavy snow roller.

All these profiles show that a fairly thin layer of surface snow was disturbed. This set up in a layer that would hold a skier but not a succession of skiers all turning at the same place. None of the plots indicated much disturbance to the underlying depth hoar which is extremely unstable and loose. With these conditions existing, it does not take long for the skier to penetrate the top layer of snow and then proceed to the ground. These plots were taken later in the winter and may bring up the question that the testing was unfair. Perhaps if the machine packing were started earlier in the season this condition of underlying unstability might be alleviated. However, this method of packing is exactly what is done at Winter Park but to very little avail.

With the continuous cold temperatures and light snowfalls, the unstable depth hoar is formed under the packed snow so that profiles shown in plots 8 through 12 are almost always present.

These series of plots indicate that machine packing is not the whole solution for the prevention of moguls.

The final solution may be the application of salt and normal machine packing and skiing in the early season plus the continuation of the process at intervals throughout the winter. Adequate packing appears to depend on sufficiently high specific compaction pressure - at least that of a man on foot.

Additional information:

Plots were laid out at Midway, the lower terminal of Meteor T-Bar, at an elevation of 9500'.

The average daily mean temperature for Fraser is as follows:

Nov. - 22.9° F)		
Dec. - 15.4°)	Long term Weather Bureau data	
Jan. - 12.7°)		
Feb. - 15.5°)		

The average daily mean temperature could be expected to about 2° warmer at Winter Park due to elevational difference.

The PSI (pounds per square inch) of the Kristi which was used to make the test plots was .4 PSI. This Kristi was a flat bed type without cab.

The PSI of the Oliver is 1.5.

The PSI of average weight boot packer on one foot is 3.5.

The PSI of average weight ski packer on one ski is 0.7.

The weight of the light roller is approximately 80 lbs. Dimensions of Roller are 30" diameter x 4' long. If area of contact with snow is 480 sq. inches, a minimum value, then PSI is 0.17.

The weight of the heavy roller is approximately 1000 lbs. Dimensions of roller are 36" diameter x 6' wide. If area of contact with snow is 800 sq. inches, a minimum value, then PSI is 1.25.

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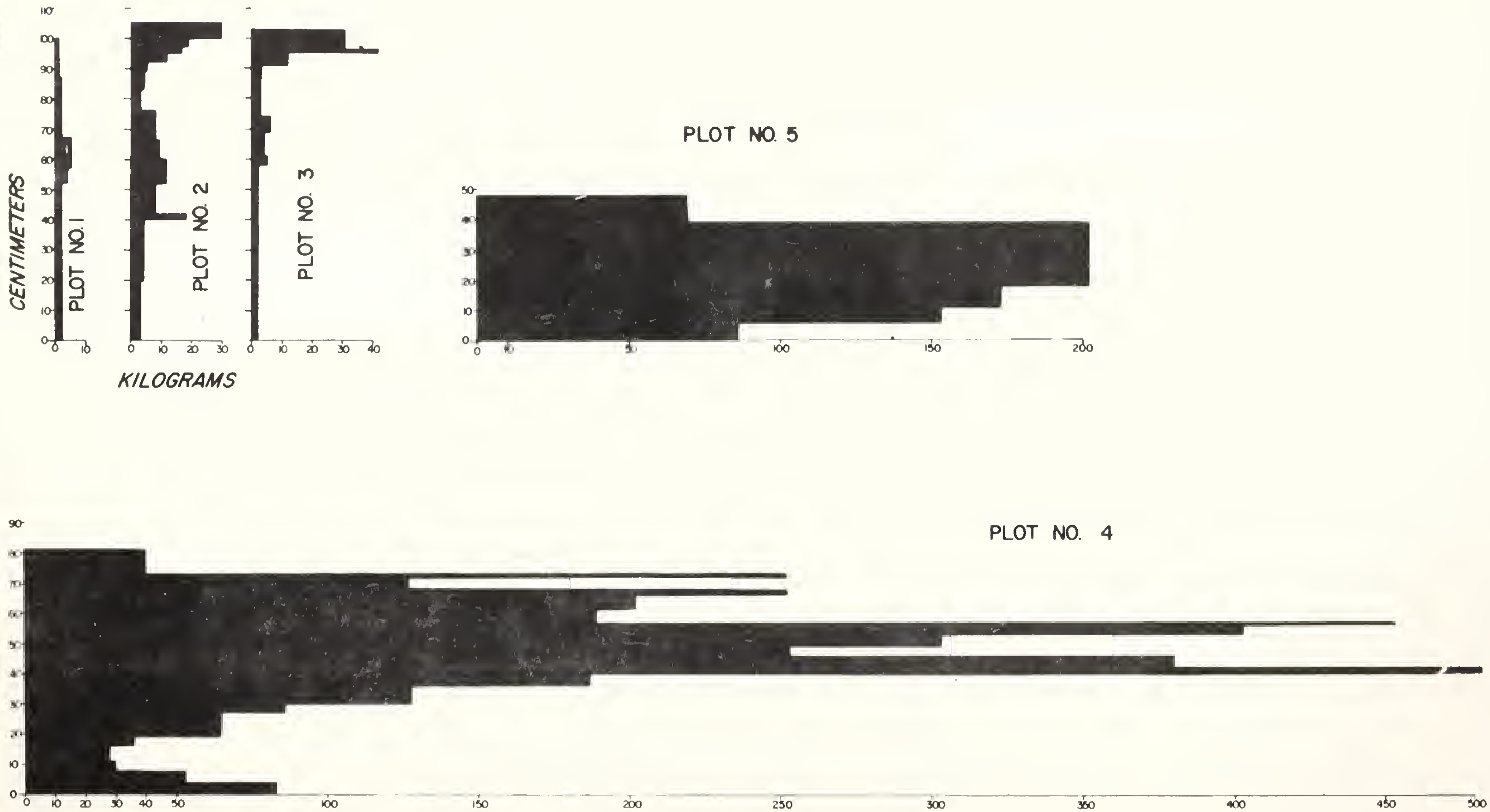

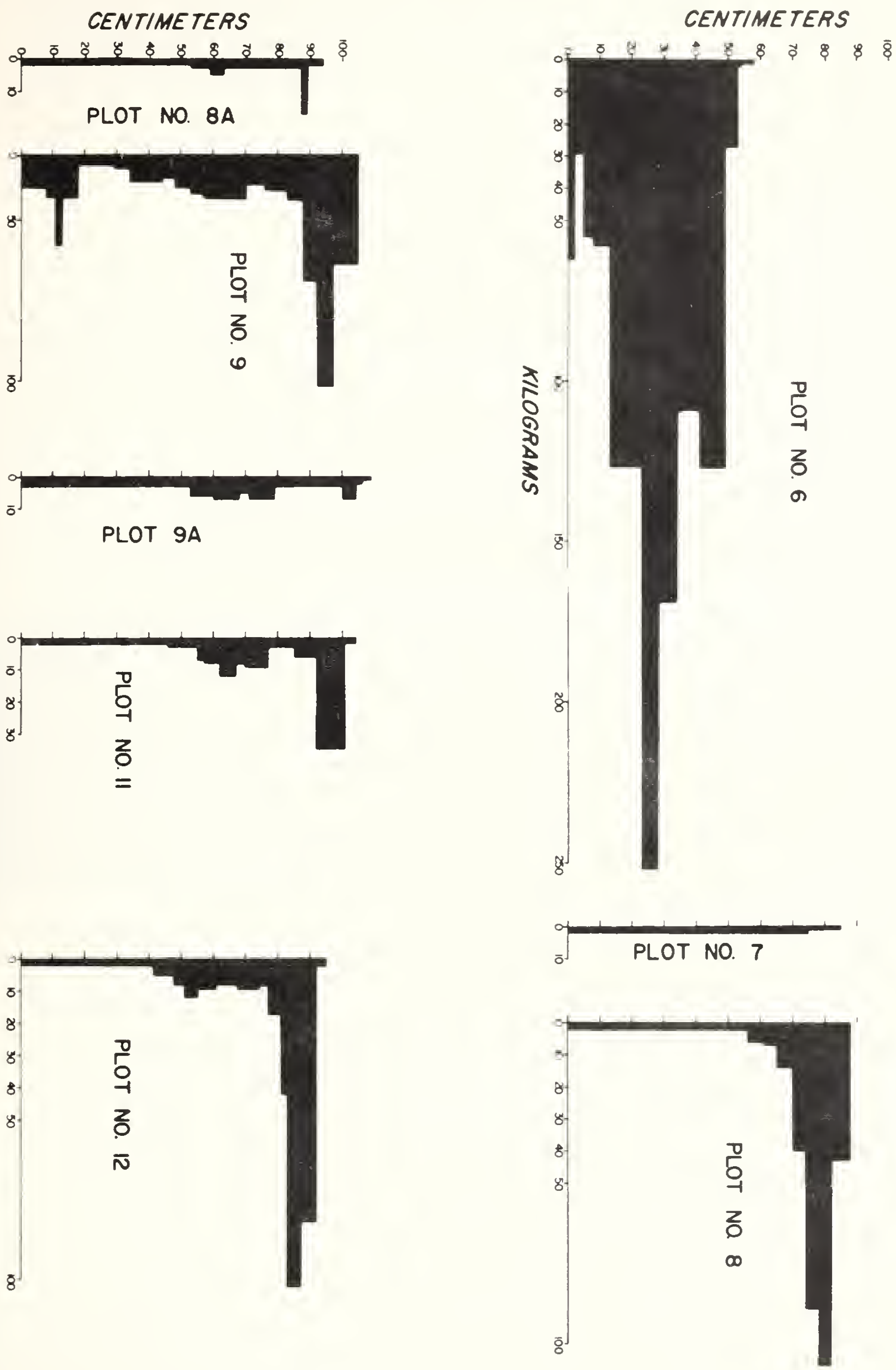

R M Stillman 5/15/62
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